Development of an asthma specific job exposure matrix and its application in the epidemiological study of genetics and environment in asthma (EGEA)

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Abstract

***Objectives*—To develop a method suitable for estimating exposure risks in population studies of asthma from job titles and international codes, by combining a new job exposure matrix (JEM) with the expert judgement approach. The method was applied in the French epidemiological study of the genetics and environment in asthma (EGEA).**

***Methods*—The JEM contains 22 exposure groups including 18 high risk groups based on known risk factors for occupational asthma, divided into high molecular weight agents, low molecular weight agents, and mixed environments. After applying the JEM to job codes, exposure estimates for each subject were re-evaluated by examining job title texts. Three high risk exposure estimates for asthma were compared: firstly, applying the JEM to original codes (from different coders in each study centre); secondly, applying the JEM to revised codes (from one experienced coder); and thirdly, after reviewing JEM exposure estimates in the light of job title texts.**

***Results*—The study comprised 173 cases with asthma and 285 controls (age 18–65). Odds ratios (ORs) for asthma for high risk jobs were 1.0 (95% confidence interval (95% CI) 0.6 to 1.7), applying the JEM to original codes; 1.4 (95% CI 0.8 to 2.3), applying the JEM to revised codes; and 1.7 (95% CI 1.1 to 2.7), applying the JEM and subsequently re-evaluating exposure estimates from job title texts. Asthma ORs were 1.4 (95% CI 0.6 to 2.9) for high molecular weight agents, 2.3 (95% CI 1.2 to 4.4) for low molecular weight agents, and 2.1 (95% CI 0.9 to 5.2) for mixed environments.**

***Conclusions*—This asthma JEM, when enhanced by expert re-evaluation of exposure estimates from job title texts, may be a useful tool in general population studies of asthma. In this study, a 1.7-fold increase in prevalence odds of high risk exposures was found among asthmatic workers compared with controls, with risk magnitude varying for different classes of exposure.**

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Occupational asthma can be caused by exposure to many substances, therefore exposure-response studies must either limit themselves to one type of work, or group varied exposures into meaningful categories. In industry specific studies, it is often possible to measure some aspect of exposure to the suspected agent—for example, intensity, duration, frequency of peaks. However, conclusions drawn are often limited by small population size and by the fact that workers who develop symptoms often leave exposed jobs. Population based studies overcome this healthy worker effect and can provide information about the overall burden in the population of occupational asthma. However, in population based studies, risk of exposure must be estimated for many potential aetiological agents.

Two surrogate measures of exposure often used in population based studies are reported exposure to specific substances or job and industry titles or tasks. The potential limitation of the first approach is that asthmatic workers may be more likely to report certain exposures than non-asthmatic workers, especially if the exposure aggravates asthma (even if not causal). Job and industry titles are less subject to recall bias, but are themselves poor surrogates for exposure to specific agents.

In recent years, two methods have emerged for estimating specific exposures with job and industry titles or tasks. One method is to merge the job titles with an external job exposure matrix. External job exposure matrices are relatively easy to apply, provided the jobs in the study are coded to match the job codes in the matrix. However, their use is reduced because the standard job coding systems generally group jobs into coding classes, developed for econometric, not health, purposes. External job exposure matrices were developed and used first for population based studies of cancer,[1 2] and have been used less often in studies of other occupational disorders,[3 4] including respiratory disease.[5 6] The recent analysis on asthma in the European Community respiratory health survey[6] used a matrix that classified exposure into broad general categories (mineral dust, biological dust, etc). We are not aware of any job exposure matrix designed specifically to capture exposures relevant to occupational asthma.

The second approach for estimating exposures with job titles and tasks has been to use professional judgement of occupational hygiene experts. Here, the occupational record of

Table 1 Categories of exposure on the exposure axis of the job exposure matrix

Low risk:
Unlikely to be exposed to substances associated with risk of asthma or to other irritating chemicals
Possible exposure to other substances (not typically associated with asthma):
Low level exposure to chemicals which may or may not be sensitisers
Exposure to irritants, but not high peaks (in construction, mining, etc)
Exposure to exhaust fumes and environmental tobacco smoke
High risk:
Jobs with a moderate or high probability of exposure to agents associated with occupational asthma:
High MW agents:
Derived from animals:
Rodents, livestock
Fish, shellfish
Arthropods or mites
Derived from plants:
Latex
Flour
Other, miscellaneous
Bioaerosols (moulds, endotoxins, etc)
Biological enzymes
Low MW agents:
Highly reactive chemicals (cross linking agents)—(anhydrides, amines, reactive dyes, glues, biocides, others, etc)
Isocyanates
Sensitising drugs
Industrial cleaning agents
Wood dusts, sensitising
Metal sensitisers
Mixed environments or agents:
Jobs with high probability of exposure to components associated with metal working fluids
Jobs in agriculture with high probability of exposure to organic particulate or fumes
Textile industry production jobs
Jobs with moderate to high probability of accidental or periodic exposure to very high levels of irritant gases or fumes (peak exposures)
Individual re-evaluation required:
Imprecise exposure estimation according to the job code: requires further verification by an expert after taking into account actual job title or industry sector

each subject is reviewed in detail to assign substance-specific exposure estimates. This expert judgement approach has been shown to be more powerful than the use of a job exposure matrix. However, it is both costly and time consuming and its validity depends on the quality of the experts.[2 7 8] Some investigators have suggested combining aspects of both approaches.[2 8]

Our objective was to develop a method suitable for estimating risks of exposure in population based studies of asthma, with information on job and industry titles and standardised international codes, by combining the job exposure matrix method with some aspects of the expert judgement approach. In this paper, we describe the development of the matrix and the expert re-evaluation step, and the results of their application in the French epidemiological study of the genetics and environment in asthma, bronchial hyperresponsiveness, and atopy (EGEA).

Methods

DEVELOPMENT OF THE ASTHMA JOB EXPOSURE MATRIX

The matrix is two dimensional with job codes on one axis and exposure categories on the other. The codes are from the International Labour Organisation (international standard classification of occupations, ISCO-88).[9] This is a four digit hierarchical system, with a written coding manual containing general coding rules and a description of the jobs included in each category. It classifies jobs into 423 codes and is published in English, French, and Spanish.

The exposure axis of the matrix has 22 risk groups based on known risk factors for occupational asthma (table 1). We chose mainly grouped exposures over specific agents, as we expected most job codes would be too broad to allow valid exposure estimates for the many specific agents linked to asthma. The starting point for grouping was the list of Chan-Yeung and Malo in which over 150 chemical and biological substances are stratified into high and low molecular weight agents.[10] The scheme is hierarchical, with a few specific agents—for example, latex, isocyanates—nested within the larger groups. We included specific agents and mixed environments because the exposure axis was based on both current knowledge about risk factors and the practical constraints imposed by the coding system. Each matrix cell contains a yes or no indication of exposure. As previous research showed that job exposure matrices are optimised when specificity is favoured over sensitivity,[11] a job was classified as exposed only if the probability of exposure was expected to be high for a considerable number of subjects in that job.

The matrix also contains a category termed "needs individual re-evaluation", for job codes which we considered initially could benefit from a second look at the textual job history. This included codes for which exposures could differ greatly by industry and others for which the job codes were not sufficiently precise. For each of these, explanatory comments were included to indicate the type of re-evaluation needed. Exposure estimates for subjects classified into this category required a second step (discussed later). An abbreviated version of the matrix was distributed to a few experts on exposure assessment and occupational asthma who were outside the project, and who provided feedback on the grouping strategy and on the method for assigning exposure in the cells. The matrix was created independently of the EGEA study.

APPLICATION OF THE JOB EXPOSURE MATRIX TO THE EGEA STUDY POPULATION

The EGEA study is a case-control and family study of adult and childhood asthma designed to investigate genetic and environmental risk factors. For this study, we included only adults (age 18–65) from the case-control arm, who reported at least one job (173 cases, 285 controls). The protocol has been described elsewhere.[12 13] Briefly, asthmatic cases were recruited from hospital chest clinics in five French cities. Asthma was defined as a positive response to four questions from an initial self completed questionnaire (to remove differences in diagnosis among physicians in the different centres). Controls were mainly population based, selected from electoral rolls (65%). Some were recruited from surgery departments of the same hospital (9%) and a social security check up centre (26%). Controls were frequency matched to cases for centre, two areas of residence within centre, season, sex, and 10 year age group. Subjects were considered eligible based on a brief self completed questionnaire, and this was used to compare those tested and included in the study with those who were not seen. This comparison indicated no significant difference between participants and non-participants in response to a general question about occupational exposure (Have you ever been exposed to dust, gases, or fumes at work?). A standardised, interviewer administered questionnaire based mostly on the European Community respiratory health survey was used. Job and industry titles were written and subsequently coded with the ISCO-88 coding system. Research team members from each centre, not specially trained in occupational coding, did the coding initially. For this analysis, a research assistant with experience in occupational coding, but no specific training in occupational hygiene or asthma, entered the written job and industry information (the text) into computer data files and recoded all jobs without reference to the codes from the centres. All coding and subsequent verification steps were done blind to disease status.

INDIVIDUAL EXPERT RE-EVALUATION OF EXPOSURE ESTIMATES

To take advantage of additional information in the written job history (but lost when the matrix is merged on codes alone), we included an individual re-evaluation phase in the exposure assessment. This was done with the computer data set generated after merging the job histories with the job exposure matrix. The re-evaluation had two steps. Firstly, we reviewed the industry and job titles for every subject in the "needs individual re-evaluation" category to decide whether to change any of the exposure assignments. For example, according to the ISCO-88 coding manual both automobile body shop workers (likely to be exposed to isocyanates) and general sheet metal workers (not likely to be exposed) are given the same code. During the individual re-evaluation, subjects can be identified with this job code who are automobile spray painters (based on the text entry) and the individual exposure classification adjusted accordingly. Secondly, the entire data set was sorted by exposure group and job code and viewed on the computer screen. Thus, it was feasible to review the job title and industry text information for every subject classified in each exposure group, and to correct further obvious coding or misclassification errors. Computerisation of the textual job history information made it possible to do this efficiently. Changes in exposure codes after the re-evaluations were identified as either due to coding errors or to lack of specificity of the job coding system. As with all previous steps, these changes were carried out blind to asthma status.

DATA ANALYSIS

To assign exposure risk groups to each study subject (rather than each job), the job held at the time of onset (or re-emergence) of asthma was found and exposure risk estimates carried out for that job. For subjects whose asthma started in childhood and continued without remission, exposure estimates were based on the current job. For most controls, exposure estimates were based on the current job. However, a subset of controls was selected at random to have their exposure estimate based on the previous job, so that the proportion of controls with risk estimates based on the previous job was similar to that of the cases. Analyses were carried out with SAS-PC, V6.12 (SAS Institute, Cary, IN, USA).

Results

DESCRIPTION OF THE POPULATION

A total of 173 cases and 285 controls comprising 680 person-jobs (with 187 different job codes) were studied. Cases and controls did not differ for mean age (cases 42.4; controls 43.7), age starting work (cases 19.4; controls 19.8), or sex (cases 47%; controls 50% female). Cases were more likely to be former rather than current smokers (38% of cases, 25% of controls, $p<0.01$) but the proportion of non-smokers was similar in both groups (42% of cases, 47% of controls). A total of 36 controls (12.9%) were classed as having a history of asthma based on a reported history of breathlessness associated with wheezing, or a history of asthma attacks.

Among both cases and controls, about 70% held white collar jobs (managerial, professional, technical, sales, or office workers) and there were no systematic differences between cases and controls for broad occupational groupings or industry sector.

For 64 of the cases (37%), asthma first appeared before the age of 18. Of these, 17 reported that the asthma disappeared during childhood and reappeared in adulthood. Thus, 126 (73%) of the cases reported asthma that either started or reappeared in adulthood (mean age at start, or reappearance, 34.0). For all but 10 cases with adult onset (or reappearance of) asthma, the date of onset coincided with the current job period.

Table 2 Examples of changes made during re-evaluation step

ISCO job code or title	*Matrix exposure group*	*Possible change required*
Examples showing lack of specificity of the ISCO job codes:		
2230 Nurses and midwives	HMW, latex	Class as not likely exposed for public health or self employed; class as exposed for surgeons, anaesthesiologists
2221 Physicians		
3133 Medical technologists	LMW, highly reactive chemicals	Class as exposed for radiology and histology technicians
3221 Medical assistants		
3211 Life sciences technicians	HMW, derived from animals	Class as exposed if job title suggests laboratory animal exposure
3220 Health science technicians		
3470 Intermediate artistic occupations	LMW, highly reactive chemicals, metal sensitisers	Class as exposed if job title suggests pigments, theatrical smokes, metal fumes
7311 Precision instrument technicians	LMW, highly reactive chemicals, metal sensitisers	Class as exposed for dental prosthesis lab technicians, artisans
7213 Sheet metal workers	LMW, isocyanates	Class as exposed for motor vehicle body shop workers
7231 Vehicle mechanics		
Examples showing the need for information on industry before coding exposure:		
1311 Managers, agricultural industries	Mixed, jobs in agriculture; HMW, derived from animal; bioaerosols	Class as exposed if evidence of job as owner, or operator
1318 Managers, personal care	LMW, industrial cleaning agents	Class as exposed if evidence of job as owner, or operator
8284 Assembly worker: metal, plastic, rubber products	LMW, highly reactive chemicals, metal sensitisers	Class as exposed depending on industry

HMW=high molecular weight; LMW=low molecular weight.

RECODING OF JOB TITLES, APPLICATION OF THE JOB EXPOSURE MATRIX, AND EXPERT RE-EVALUATION

Recoding of the 680 job titles by one trained coder resulted in 270 changes in codes compared with original codes from the six centres; however, most did not result in a change to exposure risk estimations. Only 11 subjects (2.4%) moved from a low risk into a high risk category and 15 (3.3%) from a high risk group to a low risk category. After merging the matrix with the revised codes, 97 subjects (21%) were classed in the needs individual re-evaluation category. One investigator (SK) reviewed these (blind to disease status) and exposure risk groups were changed for 23 subjects (5%). Of these, 17 were from additional information in the written job title (n=13) or industry (n=4) and six were from coding errors identified during this step. Examples of the most common codes requiring changes are shown in table 2.

The second step of the re-evaluation phase (sorting by exposure class and viewing all job history records contained in that class for obvious discordant entries) found 12 more coding errors. Ten of these resulted in the subject moving from a low risk to a high risk job code. This step required the evaluator to have knowledge of the risk groups for the job codes, as the criteria for deciding if a coding error should be corrected was if the change would result in a change in risk of exposure. This was to avoid unnecessary effort being expended in correcting a job code from one low risk code to another low risk code—for example, correcting a secondary school teacher incorrectly assigned to a social scientist job code. In total, the individual expert re-evaluation phase resulted in changes in exposure estimation for 35 subjects, with changes in overall categorisation of risk for 29 subjects (6.3%). Of these, 21 changed from low to high risk, and eight from high to low risk.

EVALUATION OF OCCUPATIONAL RISK FACTORS FOR ASTHMA

Table 3 displays the odds ratios (ORs) for asthma for high versus low risk of occupational exposure, according to the various steps in the development of the method: firstly, the matrix applied to the original job codes from the six centres; secondly, the matrix applied to the revised job codes from a single trained coder; and thirdly, the matrix applied to the revised job codes plus the two types of changes resulting from the individual re-evaluation step (coding errors corrected and exposure estimates revised after review of job title and industry texts). The OR increased in magnitude after each step.

Odds ratios for specific exposure categories (based on the final exposure group) are shown in table 4, for exposures categorised into three groups: high molecular weight, low molecular weight, and mixed environments, and for those specific exposure categories with at least five exposed subjects. Significantly increased ORs were found for exposure to all low molecular weight agents combined (and in particular, to reactive chemicals and industrial cleaning agents). Odds ratios greater than 2.0 (but with 95% confidence intervals (95% CIs) spanning 1.0) were found for exposure to bioaerosols, metals, and to mixed environments, combined. Odds ratios close to or somewhat less than 1.0

Table 3 Comparison of risk estimates of occupational asthma for high v low risk exposures, according to the stages of verification of job codes

	Cases/controls (n)*	*Cases/controls (% high risk)*	*OR (95% CI)*
n (total)	173 / 285		
JEM applied to original job codes	172 / 282	17.4 / 16.7	1.0 (0.6 to 1.7)
JEM applied to jobs after recoding by experienced occupational coder	172 / 285	19.2 / 14.4	1.4 (0.8 to 2.3)
JEM applied to jobs after recoding as above, and after further correction of coding errors detected during re-evaluation step	172 / 285	23.3 / 16.8	1.5 (0.9 to 2.4)
JEM applied to corrected job codes as above, plus revisions of assignments to risk group based on review of job title and industry text information	172 / 285	24.4 / 16.1	1.7 (1.1 to 2.7)

*After recoding it was possible to code the job titles for three additional controls; for one case, it remained impossible to code the job title.

Table 4 Specific exposure group frequencies and asthma risk estimates (univariate)

	Cases/controls (n)	*OR (95% CI)**
n (total)	172 / 285	
High MW agents, combined	15 / 20	1.4 (0.6 to 2.9)
Animal danders	2 / 3	
Fish or shellfish	0 / 0	
Arthropods, mites	0 / 1	
Latex	9 / 11	1.5 (0.5 to 4.1)
Flour	1 / 3	
Other plant antigens	0 / 0	
Bioaerosols	5 / 4	2.3 (0.5 to 11.8)
Enzymes	1 / 3	
Low MW agents, combined	26 / 21	2.3 (1.2 to 4.4)
Highly reactive chemicals	17 / 12	2.6 (1.1 to 6.2)
Isocyanates	1 / 2	
Drugs	4 / 3	
Industrial cleaning agents	8 / 2	7.4 (1.4 to 71.7)
Wood dusts	1 / 2	
Metal sensitisers, fumes	7 / 5	2.6 (0.7 to 10.5)
Mixed environments, combined	14 / 12	2.1 (0.9 to 5.2)
Metal working fluid environments	4 / 3	
Agriculture	2 / 2	
Textile production	5 / 5	1.8 (0.4 to 8.1)
Irritant peaks	3 / 2	

*ORs were calculated only for groups with five or more exposed cases and exact 95% CIs are shown. The reference category included other subjects not in any of the high risk categories (n=379).

were found for the other low risk exposure groups identified in the job exposure matrix. Logistic regression analysis, taking into account exposure group, smoking, sex, and age showed no changes in the risk estimates.

Removing from analyses the 36 control group subjects with a history of asthma resulted in no difference in the risk estimates described—for example, OR for high versus low risk exposure was 1.8 (95% CI 1.1 to 2.9). However, removing subjects whose asthma started in childhood (64 cases and 13 controls), leaving only the adult onset cases, resulted in higher risk estimates for exposure to low molecular weight agents (OR 2.7, 95% CI 1.4 to 5.1) and mixed environments (OR 3.0, 95% CI 1.3 to 6.7) but no change in the risk estimate for exposure to high molecular weight agents.

Discussion

We have created and applied a method for assigning subjects to categories of risk of asthma from occupational exposure based on job titles and industry, suitable for use in population based studies of asthma. The exposure axis of the job exposure matrix was based on current knowledge of risk factors for asthma. Other population or case-control studies of occupational risk factors for asthma have either grouped job or industry title without merging them to a matrix,[14–17] relied on external job exposure matrices not specifically designed for asthma,[5 6 18] or used an internal matrix based on the job frequency of positive response to a generic question—such as, have you been exposed to dusts, gases, or fumes?[19] An asthma specific matrix should result in more valid risk estimates for the exposures relevant for occupational asthma, and allow exposures to be grouped into categories with different biological significance. For example, it is possible to evaluate the differential pathogenesis, natural history, and secondary risk factors for asthma caused by high molecular weight versus low molecular weight agents, and asthma caused by peak exposures to irritants.

Other job exposure matrices have used probability of exposure as the cell entry[2] and this has been shown to provide more valid estimates of risk ratios.[20] However, given the lack of knowledge about the most appropriate way to measure exposure for studies of occupational asthma (intensity, duration, frequency, or probability of peak exposures), we thought it prudent to be conservative by using yes or no. We also chose to classify a job as exposed only if it had a moderate to high probability of exposure conditions associated with occupational asthma. This choice of specificity over sensitivity has been shown to reduce misclassification bias when exposure prevalence is low.[21] To counteract this we included several low risk categories to allow the possibility of detecting increased risks for these low probability, low intensity exposures, if they existed. The fact that these exposures were not associated with increased risk of asthma supports the choice of specificity over sensitivity.

One weakness of basing the exposure axis on known risk factors is that it limits the opportunity to identify risks associated with unknown agents and to recommend reduction of exposure to specific agents. We considered including more agents, but rejected this in favour of mostly grouped exposure, due to feasibility. However, the hierarchical design (with a few well identified specific substances nested within larger exposure groups) makes it possible to modify the matrix as new knowledge emerges. This will allow backward comparability, as new categories can be nested in the same larger groupings in subsequent iterations of the matrix.

To make valid exposure estimates in a study of asthma it is necessary to determine the relevant exposure time. This is most likely the job just before onset of asthma symptoms. This contrasts with exposure estimation for studies of mortality, cancer, or chronic obstructive lung disease, where it is more appropriate to sum exposures over several previous jobs. We based exposure estimates on the job held at the time of onset of asthma, except for subjects with childhood asthma, for which the current job was used. The fact that risk estimates were stronger when analyses were restricted to subjects with adult onset asthma underscores the importance of matching the exposure estimate to the relevant job. A healthy worker bias could still have been present if asthmatic workers changed jobs after the onset of symptoms but before diagnosis.

The use of a method based on job and industry titles overcomes potential bias inherent in basing exposure estimation on questions about specific exposures that may elicit responses differently by asthmatic and non-asthmatic workers. Although the reliability of self reported work histories varies from 70%–80%,[22 23] there is no indication of differential accuracy by disease. However, job titles are not close surrogates for exposure to specific substances; thus the need for the job exposure matrix. Nevertheless, our results underscore some of the limitations of a job coding system

for the job axis of the matrix that was not designed for the study purpose.

Previous research in exposure assessment for epidemiology has shown that if there is a true relation between exposure and disease, random errors in assigning subjects to exposure categories result in a risk estimate closer to the null hypothesis.[24] If we assume a true relation between exposure to occupational "asthmagens" and asthma, the stepwise increase in ORs shown in table 3 suggests that validity of the assignment of exposures increased at each step as exposure misclassification was reduced. The importance of accurate job coding in reducing misclassification error is evident from the increase in risk estimates found as the coding accuracy increased. The expert re-evaluation step, made possible by the simple expedient of including text as well as codes in the computerised data files, further enhanced the validity of the exposure estimates. With supplemental text information we were able to counterbalance the lack of specificity of the ISCO coding system, for some participants. It should be emphasised that during the re-evaluation, the evaluator must be familiar with the matrix and with the general exposure conditions of common jobs in the study population, when making decisions about which coding errors are worth correcting. It was often necessary to choose from among several possible correct job codes, and knowledge of the exposure risk categories in the job exposure matrix was useful in making a choice among codes.

We did not detect the increased risk associated with some of the most well known causes of occupational asthma. We think that this was due to both lack of specificity of job titles (not just codes) and the low prevalence of these exposures. For example, it was almost impossible to find if a study subject was exposed to laboratory animals or, with a few notable exceptions, to isocyanates, based on either the job codes or the job and industry titles.

The general strategy embodied in the re-evaluation step—that is, modifying computer generated risk estimates with additional information—could also be applied to additional information from other sources. In future studies, it may be worthwhile to enhance job histories by including more detail in the text field and a few supplemental questions to clarify exposure potential for jobs known to be difficult to classify by the matrix. This would be similar to the approach developed for case-control studies of cancer, in which sets of branch questions are incorporated into computer assisted questionnaires about work histories.[25] However, care would need to be taken to ensure that bias was not introduced through this enhancement.

For this method to be useful in more than one population based study, it should be reproducible as well as valid and able to be applied consistently by different investigators in different parts of the world, using different languages. The use of a standardised international job coding system with detailed instructions for assigning jobs to codes should increase consistency of this method, provided the coding is performed by a well trained coder. The reproducibility of the re-evaluation step will depend on the extent to which the evaluator is familiar with exposures in the jobs represented in the study population. We have added comment fields to the job exposure matrix itself, to guide evaluators in considering exposure assignment changes for certain job codes, in an attempt to standardise this step. However, its reproducibility has not yet been tested.

The interpretation of the results from studies with this method will also depend on characteristics of the study populations. The results of this study and others[11 21] suggest that the impact of differences in study power due to differential specificity of job codes will depend on the prevalence rates of exposure in the populations. This limitation should be kept in mind when interpreting the results. The failure to find an association between exposure to high molecular weight agents and asthma in this study may reflect the low prevalence of these exposures in the study population combined with the low specificity of the relevant job titles.

Our results suggest that occupational exposure plays an important and unrecognised role in asthma in the general population. In the cities in the EGEA study, asthmatic workers with recognised occupational asthma would more likely have been seen at occupational clinics, not the respiratory clinics from which the cases in this study were recruited. The increased risks identified here are more likely to be those risk factors for occupational asthma less recognised in general medical practice. This may also have contributed to the lack of relation found with high molecular weight agents, as these asthmatic workers may be more likely to be recognised as having an occupational aetiology.

Overall, our results suggest that the job exposure matrix developed for this study, when enhanced by the expert re-evaluation step, can provide a useful adjunct to general population studies of asthma. This will facilitate comparisons across study populations and estimations of the population attributable risk for occupational asthma. Future enhancements to the method could include refinements to the matrix itself (provided the existing hierarchical structure is maintained) and supplementary questions or strategies for improving the validity and reliability of the expert re-evaluation step. Copies of the matrix are available on computer disk from the authors.

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